PROCESSING FEED INGREDIENTS: COSTS, LABOR, AND CAPITAL REQUIREMENTS

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PREFACE

This study was made by the U.S. Department of Agriculture to analyze another important phase of overall feed manufacturing: the processing operation. Major emphasis was given to labor and capital requirements. Preceding studies have pertained to warehousing, pelleting, mixing, packing, and receiving phases of feed manufacturing.

Work of this type is part of the Department's broad program of research for expanding market outlets and for increasing efficiency in marketing farm products. The farmer has a double interest in the feed industry's efficiency since he produces the feed ingredients and also purchases the feed.

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SUMMARY

Processing, or particle reduction, is an important operation in all feed mills. Approximately 60 percent of the output of a feed plant is routed through the processing center for grinding, crimping, or cracking before the mixing operation. Two model processing operations were used in this study to show both labor requirements and operating costs. The smaller model which processes 45 tons during each 8-hour shift conceivably could be part of an 80-ton feed mill. The larger model, part of a 200-ton-a-day feed plant, processes 120 tons in an 8-hour shift.

Equipment for the smaller model costs about $29,000 installed. Grinding equipment costs $9,140, or less than one-third the total cost of equipment. Crimping equipment accounts for the remaining two-thirds. Total labor, production and supervisory, required to process the 45 tons is 3.08 man-hours. About 2.58 production man-hours are used in this operation. Therefore, total processing requires approximately 0.06 production man-hour per ton.

Annual operating costs, assuming the plant operates 8 hours a day, 260 days a year, are $9,945, or 85 cents a ton of material processed. Electricity accounts for almost 50 percent of this cost. The next highest cost items, production labor and depreciation, each account for about 15 percent of total cost.

The larger model processing 120 tons in an 8-hour shift has equipment costing approximately $54,210. Grinding equipment costs nearly 60 percent of this total. About 3.48 production and supervisory man-hours are required to operate this equipment to process the 120 tons. Production man-hours for this model will be 2.78 per 8-hour shift or 0.02 man-hour per ton.

The annual operating cost for this model is $18,898 or 61 cents per ton. Electricity is the highest cost item in the operating costs; it accounts for around 50 percent of the total. Depreciation is next in importance making up 20 percent of the operating cost.

A comparison of the models' total processing costs shows that the smaller mill's cost per ton is almost 40 percent higher than that of the larger mill. Cost of crimping operations for the smaller model is more than double the larger model cost primarily because of the hours of operating. Fixed costs of crimping are spread over 4 times as many tons in the larger model. Grinding costs per ton for the models are compared at specified hours of operation. Comparisons indicate increased savings possible through increased utilization of equipment. Costs could be reduced about 35 percent if models are operating 16 hours a day instead of only 2 hours a day.

Survey mills of a similar size as the smaller model used around 0.22 man-hour per ton of processed grain as compared to the model's required labor of 0.06 man-hour per ton. In the larger model 0.02 man-hour per ton was required whereas industry plants of comparable size used an average of 0.14 man-hour.

A corn cracking model was synthesized and operating costs were calculated for various hours of operation. This process would require 0.18 man-hour per ton if it operated 2 hours per day but would be reduced to 0.10 man-hour for an 8-hour operation. Operating cost per ton would vary from $1.36 a ton to 0.58 for the same period.

PROCESSING FEED INGREDIENTS: COSTS, LABOR, AND CAPITAL REQUIREMENTS

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INTRODUCTION

The mixed feeds industry has changed rapidly in recent years with the increased demand and production of formula feeds. Some of the recent trends are: Integration of mixed feeds industry with livestock production, direct sales to farmers, increased size of farms and livestock production units, bulk delivery of mixed feeds, and growth of on-farm and custom mixing. Many of these changes have affected the firms' economic positions as well as the individual plant's production operations.

Processing and grinding of grains and feed ingredients have been increasing during recent years. Livestock feeders are becoming more specialized every year and are more aware of feeding efficiency and cost of gain. Livestock feeders are using more complete feeds to achieve greater efficiency more economically. For example, in the last few years livestock feeders have mixed hay and ground grains together to provide a complete ration. The demand has increased for a complete ration of ground hay and grain mixed with protein concentrates to be fed in either pellet or meal form. Numerous studies in past years have proven that livestock can better utilize processed grains than whole grains, and thereby give greater returns.

METHODOLOGY

Two model processing centers are constructed in this report to provide management with standards to be used in analyzing this segment of the feed plant operations. Basic data for these models were obtained from a mail survey and personal interviews of a sample cooperating in the mail survey. Other pertinent information on equipment costs, electricity rates, and wage rates--needed to complete the analyses--was obtained from both industry and Government sources.

Questionaires were sent to a selected list of 225 feed manufacturers in 34 States for the basic data used in these models. Model plants of two volume sizes, 80 tons and 200 tons per 8-hour day, were used since these seem to best represent the survey plants. Typical operations for each model were obtained from the mail survey and personal interview. These operations were in turn modified with the assistance of equipment manufacturers' engineers to provide the basic models used in the analyses. Labor standards used in the models were obtained by a similar method.

Other cost items considered in the models were estimated with the assistance of industry and Government personnel. Several of these represent average costs for the Nation and are not intended to be the actual rates for a particular locality.

PROCESSING

Grain processing is an important operation in a feed mill, whether it be a formula feed plant or a custom feed plant. The most commonly used methods of processing grains to be mixed into finished feeds are by hammermills, attrition mills, and roller mills. The texture of the processed grains is important to the appearance and palatability of the finished feeds.

The processing operation begins with the ingredients, both grains and other ingredients, in the storage bins above the equipment and includes all the work in grinding, crimping, and cracking. Movement of the materials to and from the processing equipment is also included. This work involves setting up and adjusting machines with proper material flow and checking to make sure ground material is going into the proper bin and machines are functioning properly.

This operation ends as the material is placed in storage or holding bins for the mixing cost center.

Equipment

There are several different methods and machines used in particle reduction or processing. Considerable research has been conducted in recent years to learn more about the operation of the various machines and techniques for increasing their efficiency. 1/

Hammermills

The hammermill is one of the pieces of reduction equipment most commonly used by the mixed feeds industry. It may be described as a grinder in which the grinding operation is performed by several rows of thin hammers revolving at a high speed. Actually, in a hammermill the reduction of material is accomplished by a combination of forces: Impact, shear, and attrition. These actions occur in most hammermills. It is possible to some extent to regulate each type of action by the number, design, and arrangement of hammers; type and size of screen; speed of motor; contour of grinding plates; and the mechanical or pneumatic system used to carry away the ground materials.

1/ Feed Production School Proceedings, Midwest Feed Manufacturers Association, pp. 1-42, Sept. 1960, Kansas City, Mo.

Attrition Mills

There are numerous attrition mills used by the mixed feed industry today. Some advantages of the attrition mill have been overlooked by the industry. However, more production people are becoming acquainted with these advantages and the popularity of this kind of mill has increased. Some of these advantages are: (1) Longer life, (2) less maintenance, and (3) greater tonnage per horsepower.

An attrition mill is a grinding unit which reduces particle size by the rubbing process. This process is done between two discs which have replaceable wearing plates. One or both discs may be rotated. If both are rotated, they move in opposite directions.

The mill with a single rotating disc is usually referred to as a single-runner attrition mill. This type of mill is used for shredding and coarse reduction of easily ground materials. Another important and more recent use of the single-runner mill is the blending of feeds containing liquids. Small lumps and balls of feed are formed when liquids are mixed in. These are broken up so that the finished product has a uniform appearance and texture. Feed manufacturers sometimes use this machine for cracking corn and crumbling alfalfa pellets.

Roller Mills

Until recent years the roller mill was primarily used in the flour milling industry. The one used in the feed mill has rolls rotating at the same speed, and the grain is processed by a combination action of cutting and crushing.

It is important to properly condition the grain before crimping to obtain a quality product--one that is whole and fine-textured. Grain should be heated to 160 to 180 degrees Fahrenheit, and moisture should be brought up to 16 to 18 percent. The steamer should have sufficient capacity to store the grain for at least 10 minutes.

The conditioning process for the grain is related to the percentage of moisture required to get a quality product from processing. Experienced operators can determine by visual examination when the grain has received the right amount of additional moisture. The steam used for conditioning should be as dry as possible. A 3-percent steam is considered to have about the proper amount of moisture. This dry steam should be supplied to the steamer at 80 to 90 pounds pressure.

Roller mills have become popular in livestock production areas because the nutritionists have found that roller grains are more beneficial and palatable than ground grain. Numerous nutritional tests have proven the coarse open-roller grains are more digestable than ground grains.

A roller mill, like an attrition mill, has its limitations; neither can handle ear corn. Ear corn must be crushed before the material can be processed by the roller.

All grain to be crimped or rolled should be throughly cleaned to remove extraneous materials. A magnet should be used to catch any tramp iron that might be in the grain.

A dryer following the crimping process is important for removing moisture and maintaining quality of grain in storage. This piece of equipment is overlooked frequently. The moisture should not be more than 13 percent to prevent mold from forming in stored rolled grain.

PROCESSING CENTER MODELS

Two basic model processing centers were set up using the survey and industry data. These models represent various operations in the processing centers for feed mills producing 80 tons and 200 tons of finished feed per 8-hour day.

Flow Diagram

Processed materials flow either by gravity or are conveyed from the storage bin hopper by conveyor to the hammermill and the roller mill. Gravity flow should be utilized whenever possible from the overhead bins. This eliminates many problems that are present when conveyors are used.

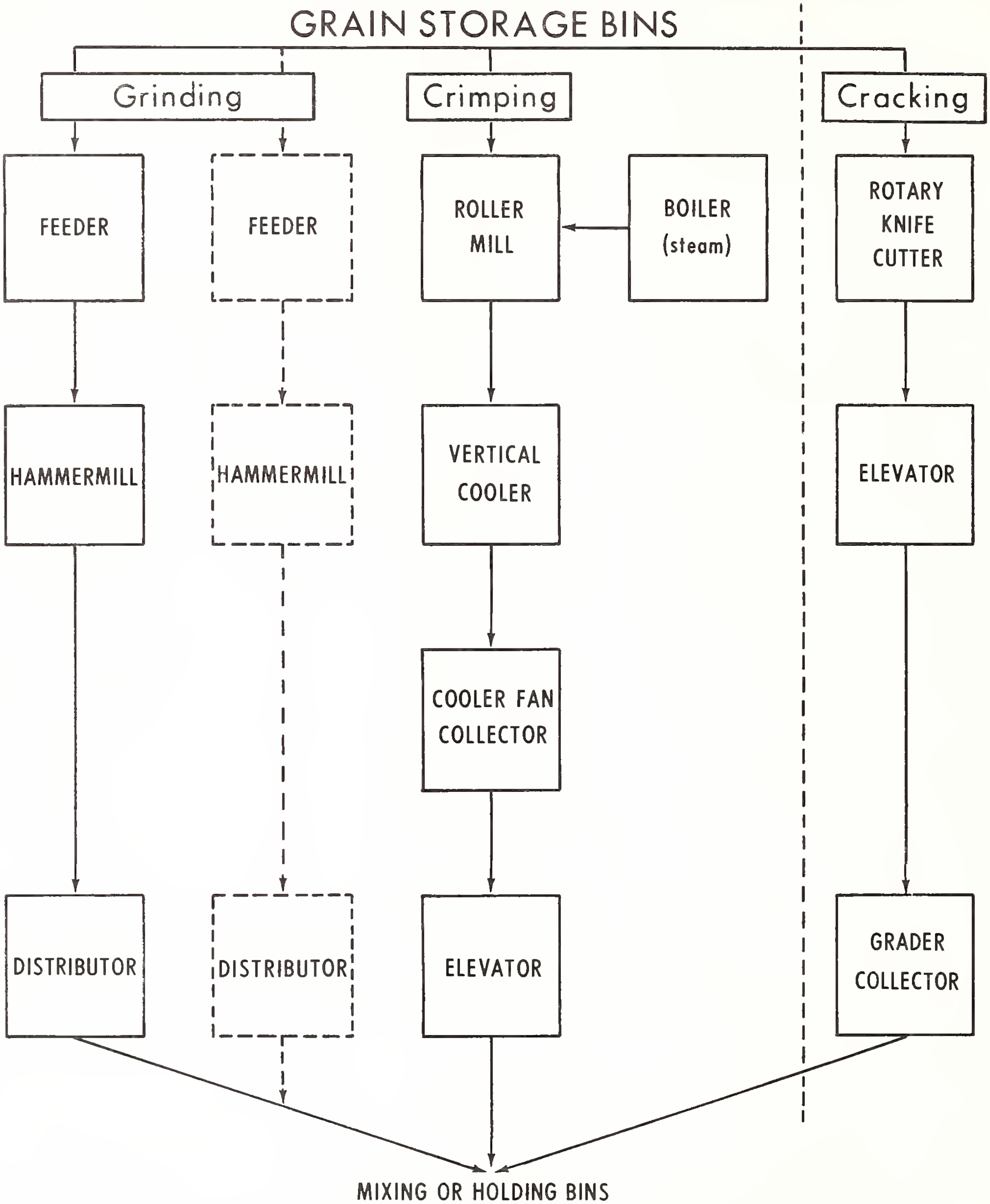
As the grain flows toward the hammermill, it encounters both a magnet and a feeder with a syphon separator which take out all the foreign material (fig. 1). After the material is ground, it is elevated to the storage bins ready for mixing. Material may be conveyed from the hammermill by an integral shaft-mounted fan, a separate motor-driven fan or a negative pressure pneumatic system. A separate pneumatic system is usually required for the higher vertical lifts.

In crimping grain, the material flows from the stroage or supply bin to the roller mill. The grain goes through a tempering conveyor or conditioner, where it is softened and expanded. This conditioning makes it possible for the rolls to crimp or spread the tough hull most effectively without reducing either the hull or the kernel. The moistened grain may be directed to the mixer for completing feed formulas, where excess moisture is absorbed; or it may be directed through a cooler or dryer. This latter equipment removes excess moisture to prevent spoilage when the crimped grains are sacked or stored in bins. An ideal situation is to have the cooler or dryer located directly below the steamer-roller and to use gravity flow.

Crimped grain may be conveyed to the storage bins with an elevator or a pneumatic system. A pneumatic system is necessary if a dryer is not used because the crimped grain is dried and cooled as it is conveyed to the storage bin via the pneumatic system.

To determine the feasibility of crimping in a feed mill, the manager must obtain the answers to several questions. First, what is the usual gross margin between whole oats and crimped oats? Second, is the quantity of crimped oats needed sufficient to keep production at an efficient level and third, is the capital required for this equipment available?

FIGURE 1—FLOW DIAGRAM FOR PROCESSING CENTER



EQUIPMENT NEEDED FOR PROCESSING CENTER OF THE 80 - TON MODEL.
DOTTED LINES SHOW ADDITIONAL EQUIPMENT FOR THE CENTER OF A 200 - TON MODEL

U. S. DEPARTMENT OF AGRICULTURE NEG. ERS 3930-65 (9) ECONOMIC RESEARCH SERVICE

An answer to the first question may be obtained rather quickly. Assuming No. 2 white oats are used for crimping, it would take about 62.5 bushels to equal a ton of crimped grain. If the market price of oats was 80 cents per bushel, a ton of oats for crimping would cost about $50. At the same time and in the same market, crimped oats was selling for $76 a ton. 2/ This leaves a gross margin of about $26 a ton which seems sufficiently high for further analyses.

The models used in this study appear to be operating at volumes which would warrant their use in the feed plant.

Labor's Duties

In processing grains and other ingredients, the process worker will be required to follow the schedule of daily requirements for processed materials established by the supervisor. Usually a larger feed mill will have more equipment because of the greater number of ingredients and volume to be processed. In a large mill the worker becomes more specialized since more man-hours are required in the processing operation.

The number of changeovers made by the operator and total time required during the day are influenced by: (1) Number of ingredients processed, (2) storage space available for processed materials, (3) types of feed manufactured, and (4) number and size of machines used. As these factors become more limited, the operator has to devote more time and attention to the work, thereby increasing the man-hours per ton of material processed.

In mills of comparable size to the models, a full-time worker is not required for processing. The operator is required to start the machine, check back and make minor adjustments while it is running, and stop it at the end of the processing operation. Most of the machines have automatic feeders to regulate the flow of grain going into the equipment and vibration controls. The equipment should have remote and standard automatic controls with indicating devices conveniently located for the processing operator.

Occasionally there may be a chokeup of a machine or an overflow which must be cleared up by the operator during the processing period. Normal housekeeping is usually required of the operator, as is the case with workers in other centers. Maintenance by the operator is limited. Replacing hammers in the hammermill and other maintenance jobs on the equipment are usually performed by the maintenance crew.

Assumptions for Model Centers

Models are operating 8 hours a day, 260 days a year. These models are assumed to be typical of the processing operations in a full-line mill with a wide range of feeds manufactured. Model operating cost data for each of these centers are based on the assumptions listed below.

2/ Whole grain and crimped grain prices were average for the month of April 1965, in Kansas City, Mo.

Type of operation.--These model centers are processing only grains which account for about 60 percent of the ingredient tonnage received or of their mixed feed production. Of this quantity of grain processed, 85 percent is ground and 15 percent is crimped. This is typical of the proportions of grain quantities processed by full-line feed mills in the survey. Corn is considered to make up the largest proportion of grain ground and oats the principal grain crimped.

Equipment.--Equipment used in the models is typical of the types found operating in the majority of feed mills. All equipment is of a capacity to provide an efficient operation. However, the equipment selected for each particular model has been made with the assistance of equipment manufacturers and engineers familiar with the requirements of feed manufacturers. Equipment has been sized and chosen for its suitability in the models. A uniform flow or machine capacity was a vital factor in selection and is important in eliminating a stoppage or slowdown in production operations. Prices of these various pieces of equipment are averages so that it may be possible to buy similar machines at a lesser cost or a higher cost. Installation of such equipment is assumed to be about 40 percent of the initial cost. Actual cost will vary with the equipment, cost of preliminary work in plants before installing equipment, and geographical location of the firm.

Wage rates.--The average hourly wage rate of $2.05 for production labor in U.S. feed mills is used in this study. 3/ This will vary greatly with geographic locality. Supervisory personnel in the models received $2.50 per hour and maintenance workers, $2.35.

Depreciation.--The straight line method of computing annual depreciation is used. An average useful life of 17 years has been assumed for most items with a zero scrap value at the end of the life period. These rates are consistent with the guidelines of the Internal Revenue Service. 4/ Depreciation charges have been kept constant regardless of the number of shifts the model is assumed to operate. However, it might be possible to increase this amount, using the rate-of-use method of depreciation as a base.

Depreciation on the facility or building space occupied by this center has not been estimated. This is a difficult item to estimate because feed plant construction costs differ widely with location, design, and type of construction.

Interest.--Interest on capital invested on equipment is included as a part of the total production expense. This is an item of expense and should be considered regardless of whether the funds were borrowed or those of the owner. Interest is estimated at a rate of 6 percent on the average investment in equipment--that is, on one-half the original investment. Interest is not included for building space utilized for the same reasons depreciation was excluded.

3/ Bureau of Labor Statistics, U.S. Dept. of Labor. Employment and Earnings, 1964.

4/ Depreciation--Guidelines and Rules. U.S. Internal Revenue Service Publication No. 456 (7-62), 56 pp., 1962.

Electricity.--Like wage rates, electricity does vary between geographic locations and sources of supply. However, an average rate of 3.25 cents per kilowatt hour is used in estimating the cost of electric power used. 5/ The total cost of electricity is calculated on a straight-line basis rather than on a growth curve which is normally done with utility rates.

Small Mill Processing Model

This model center processes about 45 tons of grain per 8-hour day. Of this amount, 40 tons are ground and 5 tons are crimped. Total finished feed manufactured by the plant would be about 80 tons per 8-hour shift. Therefore, this center would be processing about 11,700 tons of the annual mixed-feed production of 21,000 tons per year.

Equipment.--The total cost of equipment used is about $29,000 installed (tables 1 and 2). Equipment has been divided into two separate tables because of its function. Table 1 includes the equipment used in grinding grains and table 2, the crimping equipment. Not all plants in the industry crimp grain. Only particular types of livestock feeds produced utilize crimped grains in their formulas.

Total cost of grinding equipment for this model is $9,140 (table 1). All grinding of grains is done with an 18-inch, 75-hp. hammermill. A fan powered by a 30-hp. motor is used to elevate the ground grain an estimated 100 feet to the storage bin. This machine costs about $7,600 installed (table 1). A rotary wing-type feeder with syphon separator that costs about $980 removes stones, glass, and non-ferrous metals from the grain before it goes through the hammermill. Metals will be picked up by the 18-inch magnet before the grain flow gets to the grinder.

Equipment used for grain crimping will cost $19,860 (table 2). This is more than twice the cost of grinding equipment. The basic unit in this operation is an 18-inch x 24-inch roller mill which would cost about $7,540 installed. This is a roller mill with a vertical steamer; it may be used to crimp oats and steam barley, corn, oats, and milo maize. This equipment requires about 20 boiler horsepower. In the model a larger boiler is used since steam is required for other functions such as pelleting. The prorated cost of the boiler is about $4,000.

A vertical cooler with a shake feed discharge, which costs $3,240, is used for cooling the grains. When a cooler is used, it is possible to use a bucket elevator to lift the processed grain to the storage bins. If the grain is not cooled in a cooler, a pneumatic negative air system is recommended. Its cost is about 50 percent greater than the mechanical method used in the model.

Labor Utilization.--Total labor for both the grinding and crimping operations is 3.08 man-hours (tables 3 and 4). Production labor will account for 2.58 man-hours per 8-hour shift.

5/ Schedules of electric rates have been discussed with Rural Electrification Administration personnel, who state this is a reasonable rate for this type of use.

Table 1.--Quantity, cost, and depreciation of equipment for model processing center grinding 40 tons of grain per 8-hour shift

Equipment 1/	Quantity	Approximate cost 2/	Annual depreciation
	Number	Dollars	Dollars
Feeder, 18" rotary wing type with syphon separator ½-hp. varidrive motor	1	980	58
Hammermill, 18", 75-hp. fan with 30-hp. motor	1	7,600	447
Distributor, manual turn head type 10-inch x 6-hole, 45 degrees	1	560	33
Total		9,140	538

1/ Each item of equipment listed is complete with all accessories and parts necessary for complete installation.
2/ Includes installation charge of 40 percent; some items of equipment may require a higher or lower installation charge.

Table 2.--Quantity, cost, and depreciation of equipment for model processing center crimping 5 tons of grain per 8-hour shift

Equipment 1/	Quantity	Approximate cost 2/	Annual depreciation
	Number	Dollars	Dollars
Roller mill, 18" x 24", with vertical steamer, 30-hp. motor	1	7,540	444
Vertical cooler with shake feed discharge, ½-hp. motor	1	3,240	191
Cooler fan and collector 10-hp. motor	1	1,645	96
Elevator, 104' lift, 3-hp. motor 3/	1	3,435	202
Boiler (steam) 4/	1	4,000	200
Total		19,860	1,133

1/ Each item of equipment listed is complete with all accessories and parts necessary for complete installation.
2/ Includes estimated installation charge of 40 percent; some items of equipment may require a higher or lower installation charge.
3/ Alternative system for bucket elevator could be a pneumatic conveying system with a 20-hp. motor, complete with fan, collector, rotary airlock etc., $5,210 installed.
4/ Prorated on basis of percentage of plant's steam needed to condition the grain in the crimping operation. The original cost of the boiler is assumed to be about $8,000.

Table 3.--Estimated labor requirements for small model grinding 40 tons of grain per 8-hour shift 1/

Job	Labor standards	Quantity in one shift	Man-hours	Man-hour per ton
	Man-hours			
Start and adjust hammermill	0.17 per start	3 times per shift	0.51	
Check back	.05 per hour	1 time per hour	.31	
Stop and change over	.17 per stop	3 times per shift	.51	
Clean-up		0.33 per day	.33	
Allowance 2/			.33	
Total production labor			1.99	0.05
Supervision			.40	
Total labor			2.39	.06

1/ A total of 40 tons of grain are ground per 8-hour shift. Three different types of grain are ground each day. Equipment operating 6.2 hours per 8-hour shift (40 tons per day @ 6.5 tons per hour = 6.2 hours per day).

2/ 20 percent of worker's time allowed for personal requirements.

Table 4.--Estimated labor requirements for small model crimping 5 tons of grain per 8-hour shift 1/

Job	Labor standards	Quantity in one shift	Man-hours	Man-hour per ton
	Man-hours			
Start and adjust crimper	0.17 per start	1 per shift	0.17	
Check back	.05 per hour	1 time per hour	.05	
Stop	.17 per stop	1 time per shift	.17	
Clean-up	.10 per day		.10	
Allowance 2/			.10	
Total production labor			.59	0.12
Supervision			.10	
Total labor			.69	0.14

1/ A total of 5 tons of grain are crimped per 8-hour shift. Only one type of grain is crimped during an 8-hour shift. Equipment operating 1 hour per 8-hour shift (5 tons per day @ 5 tons per hour = 1 hour per day).

2/ 20 percent of worker's time allowed for personal requirements.

The grinding operation requires about 1.99 production man-hours and 0.40 supervisory man-hour per shift (table 3). Grinding equipment will operate about 6.2 hours per day to produce 40 tons of ground grain. Estimated labor requirements and time of machine operation takes into account changeover necessary to grind three types of grain per shift. This operation is primarily a machine function once it is started. Little time is necessary for periodic checks by the worker and supervisor to see that the equipment is functioning properly and the material processed meets the standards set. The grinding segment of the processing operation requires approximately 0.06 man-hour per ton processed.

Crimping grain is a processing function which is quite popular in certain geographic localities. The availability of grain, the demand for the finished product, and the cost of producing this product will determine whether the feed mill produces its own or buys the finished ingredient to be incorporated with other ingredients to meet the formulas specifications.

The model has been set up to crimp about 5 tons per 8-hour shift. This may or may not be done each day depending on the mill's needs and operating schedule. However, the model would require a total of 0.69 man-hour per day to produce 5 tons (table 4). Production labor would be 0.59 man-hour and supervision 0.10 man-hour. Only one kind of grain is processed during an 8-hour shift. Again, this is primarily a machine function and requires a minimum amount of attention after the equipment has been started. The equipment requires about 1 hour per day to produce the 5 tons of crimped grain.

Since the output is relatively small for this processing operation, man-hours per ton are larger than for the grinding function. Crimping requires about 0.14 man-hour per ton of crimped grain.

Operating costs.--Total annual operating cost for the model processing 11,700 tons of grain is $9,945 (table 5). Average cost per ton for processing this quantity is 85 cents. The most significant item of cost is electricity, which accounts for almost 50 percent of total cost. Labor, both production and supervisory, makes up only 18 percent of the total cost. This brings out the fact that grain processing is a machine operation, and only a minimum amount of labor is required. This is also evident by the fact that depreciation and interest costs account for almost one-fourth the processing center's cost per ton.

A more detailed review of costs is made by the breakdown of the grinding and the crimping operations in table 5. It cost 68 cents per ton to grind grains with the model's 10,400 tons annual production. However, crimping is a limited operation, and the facility is utilized less than 15 percent of the time. Therefore, the cost per ton of crimped grain is higher, $2.22. This could be reduced rapidly with increased utilization of equipment.

Depreciation and interest cost for the crimping function is almost twice the total cost per ton of grinding. These account for about 60 percent of this center's total cost. On the other hand, 65 percent of the grinding operation's cost is for electricity. This cost per ton might be difficult to reduce significantly because of the large quantity of electricity used. At this level of electricity use, the lowest rate has probably been established. Tables 6 and 7 provide a more detailed breakdown on number, size, use of motors, and electricity cost for each operation.

Table 5.--Total annual operating cost for small-model processing center 1/

Cost item	Grinding 40 tons (10,400 tons annually)			Crimping 5 tons (1,300 tons annually)			Total processed (11,700 tons annually)		
	Total cost	Cost per ton	Percent of total	Total cost	Cost per ton	Percent of total	Total cost	Cost per ton	Percent of total
	Dollars	Dollars	Percent	Dollars	Dollars	Percent	Dollars	Dollars	Percent
Labor:									
Production......	1,061	0.10	15	314	0.24	11	1,375	0.12	14
Supervision.....	260	.02	3	65	.04	2	325	.03	4
Depreciation......	538	.05	7	1,133	.87	39	1,671	.14	16
Interest..........	274	.03	4	596	.46	21	870	.07	8
Electricity.......	4,553	.44	65	321	.25	11	4,874	.42	49
Fuel (steam)......				410	.32	14	410	.03	4
Maintenance 2/....	367	.04	6	53	.04	2	420	.04	5
Total..........	7,053	.68	100	2,892	2.22	100	9,945	.85	100

1/ Costs are calculated using 8 hours per shift, 260 days per year.
2/ Labor cost alone: Excludes cost of replacement parts and supplies. Maintenance worker's time estimated in relation to equipment cost.

Table 6.--Annual electric power requirements and costs for small model processing center grinding 40 tons of grain per 8-hour shift 1/

Equipment and rating of motors	Rated horsepower	Kilowatt input 2/	Motor operations per shift: Times turned on	Motor operations per shift: Times required	Annual electric power: Use 3/	Annual electric power: Cost 4/
	Number	Kilowatt	Number	Hours	Kw.-hr.	Dollars
Feeder						
½-hp. motor....	0.5	0.50	3	6.2	806	26
Hammermill						
75-hp. motor....	75.0	61.40	3	6.2	98,977	3,217
Fan						
30-hp. motor...	30.0	25.00	3	6.2	40,300	1,310
Total........	105.5				140,083	4,553

1/ Assumes motors are correctly sized and will operate at full load condition.
2/ Kilowatt inputs for induction motors: Rogers, Price L., Power Factor Economics, John Wiley & Sons, Inc., 1939, N.Y., pages 23-25.
3/ Kilowatt hours (kw.-hr.) = number of hours operating per day x kw. input x number of operating days (260).
4/ Average cost per kw.-hr. used was 3.25 cents used in previous studies.

Table 7.--Annual electric power requirements and costs for small model processing center crimping 5 tons of grain per 8-hour shift 1/

Equipment and rating of motors	Rated horsepower	Kilowatt input 2/	Motor operations per shift: Times turned on	Motor operations per shift: Times required	Annual electric power: Use 3/	Annual electric power: Cost 4/
	Number	Kilowatt	Number	Hours	Kw.-hr.	Dollars
Roller mill						
30-hp. motor...	30.0	25.00	1	1	6,500	211
Vertical cooler						
½-hp. motor....	.5	.50	1	1	130	4
Cooler fan						
10-hp. motor...	10.0	8.78	1	1	2,283	74
Elevator, bucket						
3-hp. motor....	3.0	2.80	1	1	728	24
Boiler 5/........	1.0	.95	1	1	247	8
Total........	44.5				9,888	321

1/ Assumes motors are correctly sized and will operate at full load condition.
2/ Kilowatt inputs for induction motors: Rogers, Price L., Power Factor Economics, John Wiley & Sons, Inc., 1939, N.Y., pages 23-25.
3/ Kilowatt hours (kw.-hr.) = number of hours operating per day x kw. input x number of operating days (260).
4/ Average cost per kw.-hr. used was 3.25 cents used in previous studies.
5/ Estimated electricity used by boiler in heating liquids.

Large Mill Processing Model

The model is representative of a processing center in a 200-ton-a-day feed plant. Assuming the same basic production requirements, it would be possible that this same model's equipment could operate twice the length of time and approach the needs of a 400-ton-per-day mill. However, the model as set up processes a total of 31,200 tons annually. This is broken down into 26,000 tons of grain ground and 5,200 tons of grain crimped. This model is operating one 8-hour shift, 260 days a year.

Equipment.--Total cost of equipment installed for this center is $54,210 (tables 8 and 9). Grinding equipment makes up the larger portion of this cost, $32,420 or about 60 percent of the total cost.

There are two separate systems in the grinding segment of this center. These systems can be operated as individual units with each processing a particular kind of grain or as a single unit processing one kind of grain. This provides the flexibility desired in a 200-ton-a-day feed plant.

The largest cost item in this segment is the two pneumatic conveying systems which would cost $16,690 installed or about 51 percent of the total equipment cost in this operation (table 8). These are negative pressure systems each powered by 50-hp. motors. It has been assumed that in a mill of this size, the

Table 8.--Quantity, cost, and depreciation of equipment for model processing center grinding 100 tons of grain per 8-hour shift

Equipment 1/	Quantity	Approximate cost 2/	Annual depreciation
	Number	Dollars	Dollars
Feeder, 24" rotary wing type with syphon separator ½-hp. motor....	2	2,270	134
Hammermill, 24", with magnet, starter, and ammeter 100-hp. motor..........................	2	11,890	700
Pneumatic conveying system negative pressure, 135' lift complete with fan, collector, rotary airlock, etc. 50-hp. and 3/4-hp. motors.............	2	16,690	1,669
Distributors, manual turn head type, 10" x 6 hole 45°	2	1,570	92
Total......................		32,420	2,595

1/ Each item of equipment listed is complete with all accessories and parts necessary for complete installation.
2/ Includes installation charge of 40 percent; some items of equipment may require a higher or a lower installation charge.

Table 9.--Quantity, cost, and depreciation of equipment for model processing center crimping 20 tons of grain per 8-hour shift

Equipment 1/	Quantity	Approximate cost 2/	Annual depreciation
	Number	Dollars	Dollars
Roller mill, 18" x 24" with vertical steamer, 30-hp. motor..	1	7,540	444
Vertical cooler with shake feed discharge, ½-hp. motor..........	1	3,240	191
Cooler fan and collector 10-hp. motor..........................	1	1,640	96
Elevator, 140' lift, 3-hp. motor 3/........................	1	4,370	257
Boiler (steam) 4/.................	1	5,000	250
Total.......................		21,790	1,238

1/ Each item of equipment listed is complete with all accessories and parts necessary for complete installation.
2/ Includes estimated installation charge of 40 percent; some items of equipment may require a higher or lower installation charge.
3/ Alternative system for bucket elevator could be a pneumatic conveying system, 20-hp. motor, complete with fan, collector, rotary airlock, etc., $5,210 installed.
4/ Prorated on basis of percentage of plant's steam needed to condition the grain in the crimping operation. The original cost of the boiler is assumed to be about $16,000.

ground grain would be conveyed about 135 feet vertically to the storage bins. Each system is complete with fan, collector, rotary air lock with 3/4-hp. motor, manifold, piping, etc. Each system could convey up to 15 tons per hour.

Next in importance are the two hammermills. These are 24-inch hammermills powered by 100-hp. motors; they would cost $11,890. Two 24-inch wing-type feeders with syphon separators costing $2,270 are placed in the grain flow just ahead of the hammermills.

Equipment used for crimping grain costs $21,790 installed (table 9). The crimping equipment used is the same as that in the smaller model. An elevator is also used because the initial cost is only about two-thirds the initial cost of the pneumatic system required for this model. Operating costs for the pneumatic system may be higher. Twenty-five-boiler horsepower is required to supply adequate steam for this operation. A larger boiler is utilized by several centers in the feed plant, and cost has been prorated to represent the steam used in this center. Its portion of the initial boiler cost has been estimated at $5,000.

Labor utilization.--This model requires a combined total of 3.48 man-hours to handle the processing of 31,200 tons of grain, (tables 10 and 11). If the feed plant operates two 8-hour shifts, the basic assumptions concerning labor operating efficiency remain the same.

Table 10.--Estimated labor requirements for large model grinding 100 tons of grain per 8-hour shift 1/

Job	Labor standards	Quantity in one shift	Man-hours	Man-hour per ton
	Man-hour			
Start and adjust hammermill	0.17 per start	3 times per shift	0.51	
Check back	.07 per hour	1 time per hour	.27	
Stop and change over	.17 per stop	3 times per shift	.51	
Clean-up	.40 per day		.40	
Allowance 2/			.17	
Total production labor			1.86	0.02
Supervision			.40	
Total labor			2.26	0.02

1/ A total of 100 tons of grain are ground per 8-hour shift. Three different types of grains are ground each day. Equipment operating 3.8 hours per 8-hour shift (100 tons per day @ 26 tons per hour = 3.8 hours per day).
2/ 10 percent of worker's time allowed for personal requirements.

Table 11.--Estimated requirements for large model crimping 20 tons of grain per 8-hour shift 1/

Job	Labor standards	Quantity in one shift	Man-hours	Man-hour per ton
	Man-hour			
Start and adjust crimper	0.17 per start	1 per shift	0.17	
Check back	.05 per hour	1 time per hour	.20	
Stop	.17 per stop	1 time per shift	.17	
Clean-up	.30 per day		.30	
Allowance 2/			.08	
Total production labor			.92	0.05
Supervision			.30	
Total labor			1.22	0.06

1/ A total of 20 tons of grain are crimped per 8-hour shift. Only 1 type of grain is crimped during an 8-hour shift. Equipment operating 4 hours per 8-hour shift (20 tons per day @ 5 tons per hour = 4 hours per day).
2/ 10 percent of worker's time allowed for personal requirements.

About 3.8 hours of machine time are required to grind 100 tons of grain in an 8-hour shift. During this time the production worker spends 1.86 man-hours starting, adjusting, and checking back during the machine operating time. About 0.40 man-hour supervisory time is necessary to inspect this portion of the processing center's activities. Labor is more fully utilized in the model by having more than one hammermill. That is, with two hammermills it is possible to maintain one on grinding a particular kind of grain all or most of the time and using the other machine for grinding other kinds of grain as needed. The amount of check back is reduced per machine with two or more operating mills. Grinding requires 0.02 man-hour per ton with the model's level of production.

Grain crimping requires a total of 1.22 man-hours a shift to produce the 20 tons of crimped grain needed (table 11). Production labor accounts for 0.92 man-hour. Machine time required for this production is 4 hours. Crimping at this volume of output production labor per ton of finished product is 0.05 man-hour per ton. Supervisory labor increases this to 0.06 man-hour per ton.

Operating cost.--Total annual operating cost for the large model is $18,898, or 61 cents a ton of grain processed (table 12). This is the combined cost for grinding and crimping the 31,200 tons of grain processed annually.

The most significant cost items in the total cost are electricity and depreciation costs. Electricity accounts for about 50 percent and depreciation for 20 percent of the total cost. Electric power requirements and annual cost for electricity are estimated for the two segments--grinding and crimping--in tables 13 and 14.

Taking each segment separately as broken down in table 12 shows that the large model grinding 26,000 tons of grain annually can do this at an average cost of 51 cents per ton. Grinding cost per ton is about 46 percent of the cost of crimping a ton of grain. Depreciation and electricity account for a total of 80 percent of this cost of processing. Electricity is by far the largest item, 61 percent. This is an item which is most difficult to reduce as it tends to remain the same per unit of product processed at this level. Labor, both production and supervision, accounts for 10 percent of the total cost.

The model crimping 5,200 tons of grain annually would have an average cost per ton of $1.10. The most important cost item is fuel for steam--28 percent of the total. Depreciation and electricity are about the same--22 and 23 percent of the total cost, respectively. Total labor cost, including maintenance labor, is about 16 percent of the total annual cost.

Comparison of the Models' Costs

A comparison is made of the per-ton procession costs for the models (table 15). The per-ton costs have been estimated at 2-hour intervals of operation over a two-shift period. Grinding costs shown are for the two models plus a modification of the larger model. This modification is similar to the original large model except that one of the two hammermills has been removed. Therefore, the modified model must be operated twice as long or 8 hours per day to obtain the required production the larger model produces in about 3.8 hours. Too large or too much equipment, or both, resulting in overcapacity is always questioned when the equipment is not operating the major portion of the work day.

Table 12.--Total annual operating cost for large model processing 1/

Cost item	Grinding 100 tons (26,000 tons annually)			Crimping 20 tons (5,200 tons annually)			Total processed (31,200 tons annually)		
	Total cost	Cost per ton	Percent of total	Total cost	Cost per ton	Percent of total	Total cost	Cost per ton	Percent of total
	Dollars	Dollars	Percent	Dollars	Dollars	Percent	Dollars	Dollars	Percent
Labor:									
Production	991	0.04	8	490	0.09	8	1,481	0.05	8
Supervision	260	.01	2	195	.04	4	455	.02	3
Depreciation	2,595	.10	19	1,238	.24	22	3,833	.12	20
Interest	973	.04	8	654	.12	11	1,627	.05	8
Electricity	8,031	.31	61	1,342	.26	23	9,373	.30	50
Fuel (steam)	--	--	--	1,640	.31	28	1,640	.05	8
Maintenance 2/	306	.01	2	183	.04	4	489	.02	3
Total	13,156	.51	100	5,742	1.10	100	18,898	.61	100

1/ Costs are calculated using 8 hours per shift, 260 days per year.
2/ Labor cost alone; excludes cost of replacement parts and supplies. Maintenance worker's time estimated in relation to equipment cost.

Table 13.--Annual electric power requirements and cost for model processing center grinding 100 tons of grain per 8-hour shift 1/

Equipment and rating of motor	Motors	Rated horse-power	Kilowatt input 2/	Motor operations per shift		Annual electric power	
				Times turned on	Time required	Use 3/	Cost 4/
	Number	Number	Kilowatt	Number	Hours	Kw.-hr.	Dollars
Feeder:							
½ hp.	2	0.50	0.50	3	3.8	988	32
Hammermill:							
100 hp.	2	100.0	82.40	3	3.8	162,822	5,292
Pneumatic system:							
3/4 hp.	2	.75	.75	3	3.8	1,482	48
50 hp.	2	50.0	41.40	3	3.8	81,806	2,659
Total						247,098	8,031

1/ Assumes motors are correctly sized and will operate at full load condition.

2/ Kilowatt inputs for induction motors: Rogers, Price L., Power Factor Economics, John Wiley & Sons, Inc., 1939, N.Y., pages 23-25.

3/ Kilowatt hours (kw.-hr.) = number of hours operating per day x kw. input x number of operating days (260).

4/ Average cost per kw.-hr. used was 3.25 cents used in previous studies.

Table 14.--Annual electric power requirements and cost for model processing center crimping 20 tons of grain per 8-hour shift 1/

Equipment and rating of motors	Rated horsepower	Kilowatt input 2/	Motor operations per shift: Times turned on	Motor operations per shift: Time required	Annual electric power: Use 3/	Annual electric power: Cost 4/
	Number	Kilowatt	Number	Hours	Kw.-hr.	Dollars
Roller, mill with vertical steamer 30-hp. motor....	30.0	25.00	1	4	26,000	845
Vertical cooler ½-hp motor......	.5	0.50	1	4	520	17
Cooler fan 10-hp. motor....	10.0	8.78	1	4	9,131	297
Elevator, bucket 5-hp. motor.....	5.	4.47	1	4	4,649	151
Boiler 5/........	1.	0.95	1	4	988	32
Total........	51.5				41,288	1,342

1/ Assumes motors are correctly sized and will operate at full load condition.
2/ Kilowatt inputs for induction motors: Rogers, Price L., Power Factor Economics, John Wiley & Sons, Inc., 1939, N.Y., pages 23-25.
3/ Kilowatt hours (kw. hr.) = number of hours operating per day x kw. input x number of operating days (260).
4/ Average cost per kw.-hr. used was 3.25 cents used in previous studies.
5/ Estimated electricity used by boiler in heating liquids.

Table 15.--Operating cost per ton for models at specified hours of operation

Hours	Grinding 1/: Small model	Grinding 1/: Large model	Grinding 1/: Modified model	Crimping model 2/
	Dollars	Dollars	Dollars	Dollars
2................	0.97	0.64	0.65	1.49
4................	.81	.51	.52	1.10
6................	.70	.46	.47	.95
8................	.66	.43	.43	.87
10................	.65	.43	.43	.87
12................	.64	.42	.43	.85
14................	.64	.41	.42	.83
16................	.62	.40	.41	.79

1/ Small model production is 5 tons per hour, large model production 26 tons per hour, and modified large model production is one-half that of larger model or 13 tons per hour.
2/ Operating cost of crimping in the larger model.

If the equipment for the three models is operating 16 hours per day, per-ton grinding costs on the average can be reduced about 37 percent over the operating costs for 2 hours. Cost of crimping operations over the same period can be reduced about 47 percent. This comparison is used to illustrate possible savings that exist through a higher degree of equipment utilization.

Using these data with another approach brings the cost relationship of the larger model and the modified model closer to actual operations. Table 16 presents the costs for these two models at specified levels of production. There are considerable differences between the cost per ton for the individual levels of production.

Table 16.--Operating cost per ton of models at specified levels of production 1/

Tons per day	Large model: Hours operating	Large model: Cost per ton	Modified model: Hours operating	Modified model: Cost per ton
	Number	Dollars	Number	Dollars
50	2	0.64	4	0.52
80	3	.60	6	.47
104	4	.51	8	.43
156	6	.46	12	.43
208	8	.43	16	.41

1/ Grinding cost only.

The modified model's operating cost per ton tends to be lower through all specified levels of production--from the lowest level of 50 tons per 2-hour day to 208 tons per 8-hour day. Over this schedule the larger model's cost per ton can be decreased about a third. The modified model producing the same volumes but over a longer period--4 to 16 hours--a day is able to reduce the per-ton cost about 20 percent. The greatest difference between the cost of the two models occurs around 100 tons a day. At this level the larger model is operating 3 hours and the modified model operates 6 hours. With greater production, the difference in cost per ton for these models narrows. At the highest level of 208 tons a day, the modified model's cost is only 5 percent below that of operating the large model.

This question should be asked: How much does overcapacity really cost the feed manufacturer? If flexibility in operation is required, then a certain amount of overcapacity is necessary to provide this feature. Overcapacity of equipment may tend to offset some of the inefficiency resulting from an undercapacity of the storage in the facility grain bins, processed ingredient bins, etc. This is an extremely difficult question to answer because each mill is different in its layout, management, and problems affecting the mill's overall operations.

A review of survey plant data brings forth a number of interesting observations. All plants in the survey did some processing; 100 percent ground grains or other ingredients, or both; 57 percent crimped or rolled grains; and only 10 percent cracked corn.

All of the major grains (corn, oats, barley, and milo) were ground by some of the survey mills. Other major ingredients ground were grain screenings, meat scraps, beet pulp, brewer's grains, and alfalfa pellets. Grains were by far the most important in tonnage processed. Most of the grinding was done with hammermills. Only 8 percent of the mills surveyed used attrition mills.

Size and number of hammermills varied considerably among the plants in the different volume groups. About 48 percent used only one hammermill. Almost 65 percent of the mills with a total output less than 70,000 tons of mixed feed a year had only one hammermill. Mills with more than 70,000 tons annual mixed feed production tended to have more; 80 percent had two or more hammermills.

The proportion of material to be processed in relation to total output greatly affects the number of hammermills. That is, a mill producing primarily concentrate feeds would not process the proportion of the tonnage of a mill of comparable size producing complete feeds with a higher grain content.

Horsepower of the equipment ranged from 20 up to 125. Mills with an annual output of less than 35,000 tons tended to use 75 horsepower and smaller hammermills. Larger mills used the 100- and 125-horsepower larger capacity equipment. The average output of processed materials ranged between 2 and 20 tons per machine hour. The larger machines' average output was about double that of the smaller ones.

There were four major sizes of screen used by the mills. Survey plants tended to use the same size screen for all materials ground. About 27 percent of the mills used a 3/16-inch screen. Next in use were the 1/4-inch and the 5/32-inch screens, each being used by about 18 percent of the mills. The fourth major size was the 1/8-inch, which was used almost exclusively for grinding oats and alfalfa pellets.

In the 57 percent of the mills with crimping or rolling equipment, about two-thirds had only one machine. The majority of the larger plants had two or three machines. About 40 percent of the roller mills used the 9- x 6-inch rolls. The next most popular sizes were the 18- and 30-inch roller mills. Corn, oats, and barley were the major grains crimped. Production ranged from 2 to 10 tons of grain per machine hour.

The models' equipment differs from the industry data in that the equipment is more closely sized to the volume of operation. Industry plants tended to have more equipment than necessary for all phases of processing. This is likely to increase the total cost picture as well as the manpower. No doubt much of the equipment in the survey mills had been nearly or completely depreciated. A fewer number of machines of greater capacity, operating closer to capacity tend to make the entire operation more efficient. Equipment selected for the models is sized so that it does not operate a full 8 hours to process the required

tonnage. Feed-mill designers suggest that equipment capacity should be 25 to 50 percent more than the quantity required. This much capacity would provide for some expansion and flexibility in the operation as well as time during the working day which might be required for maintenance.

Feed mills in the survey tended to use more labor than required in the models. Mills in the survey similar to the smaller model required on the average 0.22 production man-hour to process a ton of grain or other ingredients. Man-hours required for the individual plants varied from a low of 0.09 to a high of 0.38 man-hour a ton. The model required 0.06 man-hour to grind and crimp the production needed.

Feed mills of comparable size to the larger model used on the average 0.14 production man-hour in the processing center. The most efficient operation used 0.07 man-hour per ton. The model processing center used 0.02 production man-hour per ton of material processed.

A comparison of the number of man-hours actually used to perform an operation and the number of manhours which should be sufficient raises several questions. What are the causes for these wide variations and differences? Are the workers spending more time in performing the functions than actually needed? Is the inefficiency in the operations due to plant layout and/or equipment? Most likely the inefficiency is due to a combination of equipment, plant layout, and labor utilization.

These data indicate the need for increased efficiency by many plants but more importantly they show that some plants in the industry have reached the levels achieved by the models. In general, the degree of efficiency attained in the processing center was reflected in the operation of the various other centers in the plant.

CONCLUSIONS AND RECOMMENDATIONS

Data obtained in this survey and previous ones clearly indicate that many feed mills should be renovated to provide for more efficient operations. Most mills will find more difficulty in the coming years in maintaining a competitive position with newer facilities within their general sales area.

Remodeling older facilities is quite frequently a greater problem than building a new one. There are numerous problems, considerations, and limitations involved in up-dating an older facility. However, there are a few basic recommendations regarding plant operations and equipment utilization which management should keep in mind. Management must remember there is no standard solution for their problem. The solution that works well for one company may be totally wrong for another because of geographic location, type of market, available personnel, type of management, etc.

Most new plants are planning their immediate tonnage requirements for an 8-hour schedule on a 5-day week. This means that they can approximately double their tonnage provided certain things are considered in the basic layout such as receiving, loadout, and adequate storage, by running 16 hours per day. In most medium and small mills, about 20 hours a day is the maximum they can safely

schedule, but few of them are doing it except those with small mills built sometime ago that are being run to the limit to prevent having to build a new plant.

Some "down time" is required for maintenance, and other personnel and equipment problems which prevent most feed mills of this type from running on a 24-hour schedule. Generally a new mill should not require more than 8 hours, and sometimes less--perhaps 5 or 6 hours--to produce its initial tonnage requirement. Few mills are being built for less than $200,000 or $300,000. With an investment of this kind, most companies will not make it unless they plan to expand considerably in the next few years. Therefore, the idea of expanding tonnage by running the second shift is a sound one.

Summarizing, if the management structure, available personnel, and market or point-of-use conditions are suitable, it is feasible for management to investigate running a mill 20 to 24 hours a day. This, of course, gives maximum utilization of equipment, with minimum depreciation and interest and other capital charges per ton of feed and has many advantages if it can be done. In case any one of the preconditions do not justify it, then management should investigate running 16 hours or less, modifying the program to suit particular strengths and weaknesses. New plants, particularly where they are in an expanding market area, should try to schedule the original design of the mill to make their initial tonnage requirement in not over 8 hours per day.

APPENDIX

Corn Cracking

Grain cracking, more specifically corn cracking or cutting, is not done as extensively as in the past years. With today's high labor cost and the decline in demand for graded cracked corn, fewer feed mills are doing this type of processing. In fact, equipment manufacturers have indicated that the once large market for this type of equipment has been declining over the last several years.

However, since a number of feed plants surveyed did some cracking, a brief discussion will be of interest to those in the mixed feeds industry who wish to relate these costs to their own processing costs. This model contains equipment similar to what might be installed in a new feed plant. (See Figure 1, page 8). The system utilizes a cutter-grader. The product is passed over a grader with an aspirating tip. All overs and fines are spouted into an offal bin for regrinding into cornmeal by the hammermill. A single finished product, combining both medium and coarse grades, is binned for use.

Equipment.--The total cost of equipment for this function is about $10,965 installed (table 17). A rotary knife cutter powered by a 7½-hp. motor costs $3,460. This unit has the capacity of 2½ tons per hour. All other pieces of equipment have been sized accordingly. Processed corn is elevated from the rotary cutter to the grader by an elevator leg which costs $2,980. A gyrowhip cracked corn grader is used to separate the cracked grain. This unit costs $4,525. From the grader, the separated materials are diverted to their respective storage bins.

Table 17.--Quantity, cost, and depreciation of equipment for model processing center cracking up to 15 tons per 8-hour shift

Equipment 1/	Quantity	Approximate cost 2/	Annual depreciation
	Number	Dollars	Dollars
Rotary knife cutter 7½-hp. motor and drive	1	3,460	204
Elevator, 104' lift 2-hp. motor 3/	1	2,980	175
Cracked corn grader, fan, and dust collector, 3/4-hp. and 2-hp. motors	1	4,525	266
Total		10,965	645

1/ Each item of equipment listed is complete with all accessories and parts necessary for complete installation.
2/ Includes installation charge of 40 percent; some items of equipment may require a higher or lower installation charge.
3/ An alternative system for bucket elevator. A pneumatic conveying system with a 15 hp. motor complete with fan, collector, rotary airlock, etc., $4,945 installed.

Labor utilization.--Labor requirements and utilization are changed significantly with increased hours of machine operations (table 18). Man-hours per ton of processed corn decreased from 0.18 man-hour to 0.10 man-hour, as machine time increased from 2 hours to 8 hours. Check-back and clean-up time increases in direct proportion to the increase in number of hours. Assuming only corn is cracked and the supply of corn and storage space are not limiting factors, then only one start and one stop per day is necessary regardless of operating time.

Supervisors' time is increased when operation is more than 4 hours. There is a certain amount of supervision necessary regardless of length of machine time. Maintaining quality of processed material and smoothness of machine operations is required whether the equipment operates 2 or 4 hours. However, above a certain level of production or machine time, more time is required for adequate supervision. In effect, the supervisor when making his rounds of plant operation may devote from one-third to almost 50 percent as much time insepcting the operations as the worker does operating the equipment.

It is possible that some time may be saved in an individual plant's processing operation if these operations are located in the same area, preferably a room in the feed plant for all processing equipment. The amount of time required for check-backs and clean-ups could be reduced.

Operating costs.--Total annual operating costs range from $1,774 for the average 2-hour-per-day operation to $3,036 for the equipment operating 8 hours, (table 19). Per-ton cost for the 8-hour operation processing 4 times more cracked corn is only 43 percent as much as the cost of the 2-hour operation.

As the production schedule is increased, the cost per ton declines for all cost items except electricity, which tends to remain constant per unit of output. With the model's increased production, labor--production and supervisory--electricity, and maintenance costs account for an increasing proportion of the total operating cost.

Electric costs have been estimated for the four basic levels of operation. The average per-ton cost tends to remain constant at 14 cents regardless of the quantity of corn cracked (table 20). This seems to be a relatively small cost per ton in comparison to electricity used in other phases of the models--42 cents for the smaller model and 30 cents for the larger model.

The greatest reduction in total cost takes place between the 2- and 4-hour operations. Cost per ton is decreased about 40 percent with the 4-hour operation. About 50 percent of the reduction is accounted for by the decreasing depreciation and interest costs.

The overall cost of the cracking operation may be reduced if the equipment is placed in the same location as the processing equipment. Labor cost does not constitute a large portion of the total cost but it is an area where labor efficiencies are possible. For example, checking back on machines may be done almost as quickly for the three processes as for one process. The equipment operator and supervisor can usually detect a malfunctioning machine by its sound or by looking at the ammeter. Clean-up time is another item which may be reduced if all processing operations are centralized.

Table 18.--Estimated labor requirements for cracking corn at specified levels of operation per 8-hour shift 1/

Job	Labor standards	Quantity in one shift	2-hour operation	4-hour operation	6-hour operation	8-hour operation
	Man-hours		Man-hours	Man-hours	Man-hours	Man-hours
Start and adjust cracker	0.17 per start	1 per shift	0.17	0.17	0.17	0.17
Check back	.05 per hour	1 time per hour	.10	.20	.30	.40
Stop	.17 per stop	1 time per shift	.17	.17	.17	.17
Clean-up	.17	1 time per 2 hours	.17	.34	.51	.68
Allowance 2/			.06	.09	.12	.14
Total production labor			.67	.97	1.27	1.56
Supervision			.25	.25	.45	.45
Total labor			.92	1.22	1.72	2.01
Man-hours per ton 3/			0.18	0.12	0.11	0.10

1/ Man-hours are estimated at various levels of machine operations per 8-hour shift; 2, 4, 6, and 8 hours running time. Each hour, equipment runs 2.5 tons of finished product (cracked corn) processed.
2/ 10 percent of workers' time allowed for personal requirements.
3/ Man-hours per ton based on actual output of corn cracked in this time period.

Table 19.--Estimated annual operating costs for cracking operation at specified levels of operation per 8-hour shift 1/

Cost item	2 hours (1,300 tons annually)		4 hours (2,600 tons annually)		6 hours (3,900 tons annually)		8 hours (5,200 tons annually)	
	Total cost	Cost per ton	Total cost	Cost per ton	Total cost	Cost per ton	Total cost	Cost per ton
	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
Labor:								
Production	357	0.27	517	0.20	677	0.17	831	0.16
Supervision	162	.13	162	.06	292	.08	292	.06
Depreciation	645	.50	645	.25	645	.17	645	.12
Interest	329	.25	329	.13	329	.08	329	.06
Electricity	189	.14	378	.14	567	.14	756	.14
Maintenance	92	.07	92	.04	183	.05	183	.04
Total	1,774	1.36	2,123	.82	2,693	.69	3,036	.58

1/ Costs have been estimated at various levels of machine operations per 8-hour shift; 2, 4, 6, and 8 hours running time.

Table 20.--Annual electric power requirements and costs for model processing center cracking 5 tons of grain per 2 hours of operation 1/

Equipment and rating of motors	Motors	Rated horsepower	Kilowatt input 2/	Motor operations		Annual electric power				
				Times turned on	Time required	Use per 2 hours 3/	Cost 4/ 2 hours	4 hours	6 hours	8 hours
	Number	Horsepower	Kilowatt	Number	Hours	Kw.-hr.	Dollars	Dollars	Dollars	Dollars
Rotary knife cutter										
7½ hp.	1	7.5	6.70	1	2	3,484	113	226	339	452
Elevator bucket										
2-hp.	1	2.0	1.87	1	2	972	32	64	96	128
Grader										
3/4-hp.	1	.75	.75	1	2	390	12	24	36	48
2-hp.	1	2.0	1.87	1	2	972	32	64	96	128
Total..........						5,818	189	378	567	756

1/ Assume motors are correctly sized and will operate at full load condition.
2/ Kilowatt inputs for induction motors: Rogers, Price L., Power Factor Economics, John Wiley & Sons, Inc., 1939, N.Y. pages 23-25.
3/ Kilowatt hours (kw. hr.) = number of hours operating per day x kw. input x number of operating days (260).
4/ Average cost per kw. hr. used was 3.25 cents used in previous studies. Each 2-hour operating period is assumed to require the same amount of electric power.

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